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Performance of Self-Adaptive Techniques for Multi-Static, Concurrent Detection, Classification and Localization of Targets in Shallow Water Using Distributed Autonomous Sensor Networks

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LONG TERM GOALS

To develop coherent space-time-frequency processing algorithms to enhance the multi-static concurrent detection, classification and localization of proud and buried targets in shallow ocean waveguides using distributed autonomous sensor networks.

OBJECTIVE

The proposed Georgia Institute of Technology (GIT) research effort will develop coherent space-time-frequency processing techniques to enhance the resonant acoustic signatures of man-made targets (e.g. elastic shells) recorded on various nodes of an autonomous distributed sensor network. Both the issues of 1) time-frequency shift of the acoustic signatures across the sensing aperture and 2) convolution of the target echoes with the multipath response of the shallow water sound channel, will be addressed.

APPROACH

These space-time-frequency signal processing techniques will applied to the analysis of the 3D multistatic acoustics collected during the SWAMSI experiment conducted in March-April 2009 in Panama City collected either on a vertical- receive array (VRA), or on a synthetic-aperture horizontal receive array (S-HRA) created from an AUV track. The 3D multistatic acoustics of seabed targets in shallow water will also be investigated numerically using the simulation frameworks developed in collaboration with MIT and NATO Undersea Research Centre, including 3D target scattering in ocean waveguides, seafloor reverberation and time-revesal acoustics for various sensor array configuration

The proposed GTech research effort will develop robust coherent space-time-frequency processing algorithms for analyzing the 3D multistatic acoustic signatures of seabed targets in shallow water in collaboration with MIT and MPL/SIO,

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14. ABSTRACT
To develop coherent space-time-frequency processing algorithms to enhance the multi-static concurrent detection, classification and localization of proud and buried targets in shallow ocean waveguides using distributed autonomous sensor networks.

15. SUBJECT TERMS

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WORK COMPLETED and PRELIMINARY RESULTS

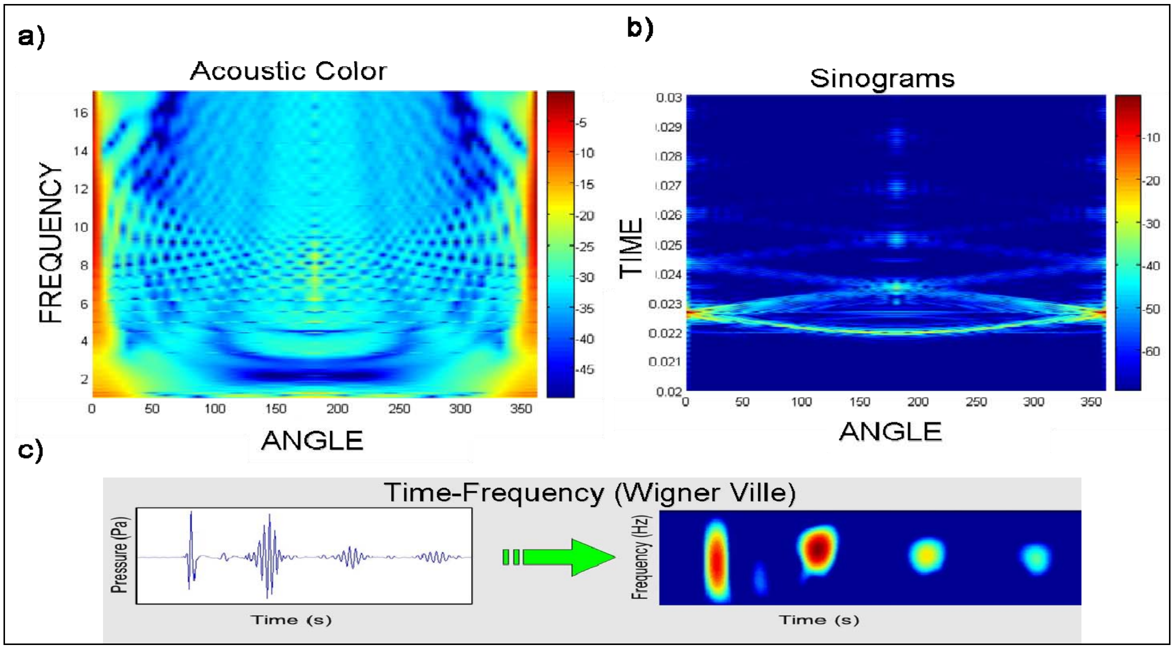

Figure 1: a) Bistatic response of an elastic shell (shell is 1m diameter, 1.5 cm thick steel) in the frequency-angle domain ("Acoustic color"). The angular variable measures the angular spacing between the source and receiver location. Note the stong coincidence pattern at Θ=180º (monostatic direction). b) Time-angle representation of the same bistatic response ("Sinogram"). The first wavefront correspond to the specular echoe and is followed by successive wavefronts corresponding the shell elastic resonances (S0,A0) circling around the shell. c) Time-frequency analysis of the backscatter response of an elastic stell (monostatic response, i.e. Θ=180º). Note the various strong resonances (narrowband) appearing beyond the firstg broadband specular echo. The locations of these resonances vary in the time-frequency plan

For underwater sonar, time-frequency analysis and, in particular Wigner-Ville analysis, has been shown to be a relevant tool for discriminating a man made target (shell) from a natural one of the same shape (solid) and even to estimate some target characteristics (shell thickness, shear velocity..). This processing tool takes advantage of the evolutional, time dependent aspect of the echo spectrum (see Fig. 1.c). The estimated time-frequency patterns can be used for detection and wideband classification of sonar echoes in order to reduce false alarms. In particular, the so-called "coincidence pattern" appearing for specific frequency range is a robust time-frequency signature of man-made shells (see Fig. 1.c). Indeed, the source-receiver configuration, target geometry (e.g. shell thickness) and medium parameters (e.g. sound speed, density) influence the evolution of the time-frequency signatures of these scattered echoes. Hence, in practice, the time-frequency content of each structural echoes of the surveyed target (e.g. Fig. 1) will vary for each of the selected multistatic source-receiver pairs or configurations.

A space-time-frequency analysis allows understanding the echo formation mechanisms and their bistatic evolution, as illustrated for instance in Fig .2. Most importantly the energetic coincidence pattern (resulting from the interactions of A0+ and A0- waves) appears to vary in the time-frequency plan when bi-static receiver angles changes. This occur since the A0+ and A0- waves shift and separate as path lengths to the receiver vary for bi-static receiver angles (see Fig. 2). Hence a coherent processing of the various echoes of the spherical shell will not be possible using conventional approach limited to the frequency domain (e.g. conventional time-delay beamforming) since the frequency content of the echoes is not constant. Instead the full space-time-frequency coherence of the echoes need to be combined to enhance detection with respect to surrounding ambient noise and reverberation due to clutter. One implemented approach is to correct for both estimated time-delay and frequency shift of the coincidence pattern (time-frequency beamforming using companded signals)

Consequently, this space-time-frequency variations of the 3D multistatic acoustics signature of elastic shells is especially challenging for concurrent DCL using conventional broadband coherent processing techniques (e.g. time-delay beamforming) since the scattered echoes are not simply a time-delayed version of each others. Hence generalized coherent space-time-frequency signal processing algorithms need to be developed to enhance the extraction of the structural echoes vs. ambient noise or clutter.

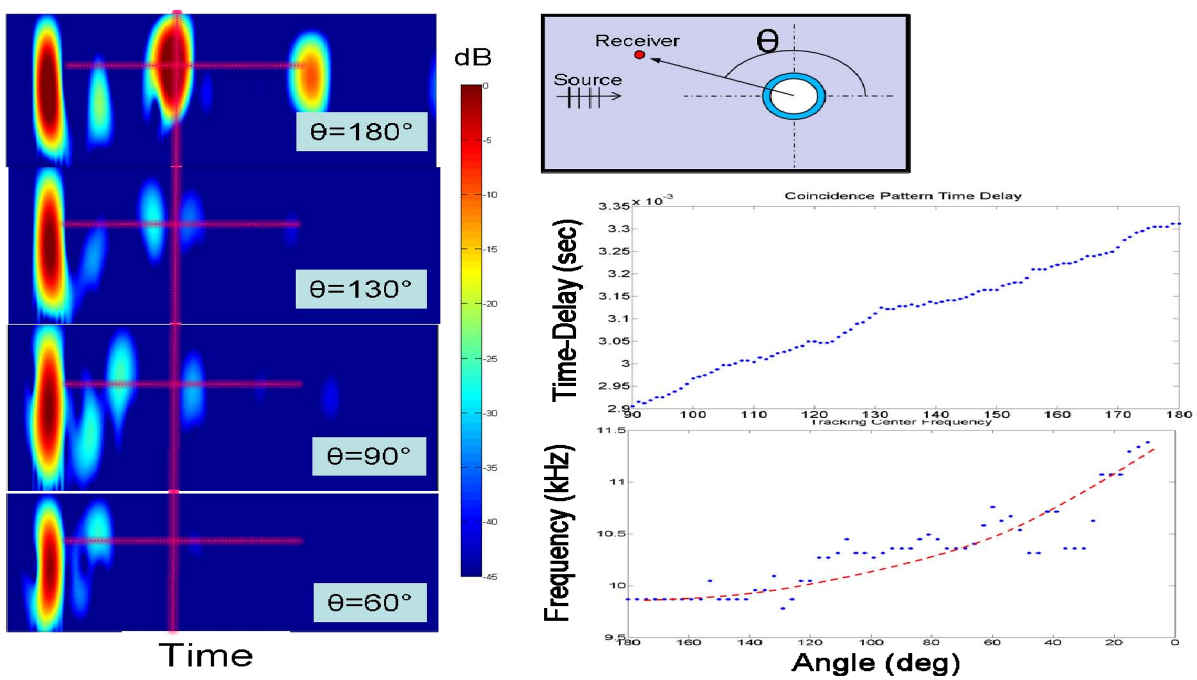

Figure 2: Splitting of the bistatic time-frequency signature of the elastic shell in two patterns (#1 and #2) corresponding to the two coherent interference of A0+ and A0- waves when their path lengths around the sphere vary (bistatic configuration). Measurements of time-delay and frequency shift of the coincidence pattern vs. bistatic angle.

IMPACT

This work is focused on developing potential MCM procedures to improve multistatic concurrent Detection, Classification and Localization of elastic target by investigating the full space-time-frequency coherence of their echoes.

PUBLICATIONS

"Time-frequency analysis of the bistatic response of elastic spherical shells" S. Anderson, K. G. Sabra. Paper in preparation.